CoSense

Feng Zhao (PI), Jim Reich, Patrick Cheung,
Julia Liu, Jie Liu, Leo Guibas, Jaewon Shin
(http://www.parc.xerox.com/cosense)

Palo Alto Research Center, Inc. (PARC)
(formerly, Xerox Palo Alto Research Center)

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PARC CoSense Project:

Collaborative Sensemaking of Distributed Sensor Data for Target Recognition and Condition Monitoring

PARC SITEX02 Objectives

- Experiment on IDSQ tracker for single vehicle, 2D tracking
- Data collection of single/multiple vehicle runs for lab experiment

SITEX02 Results

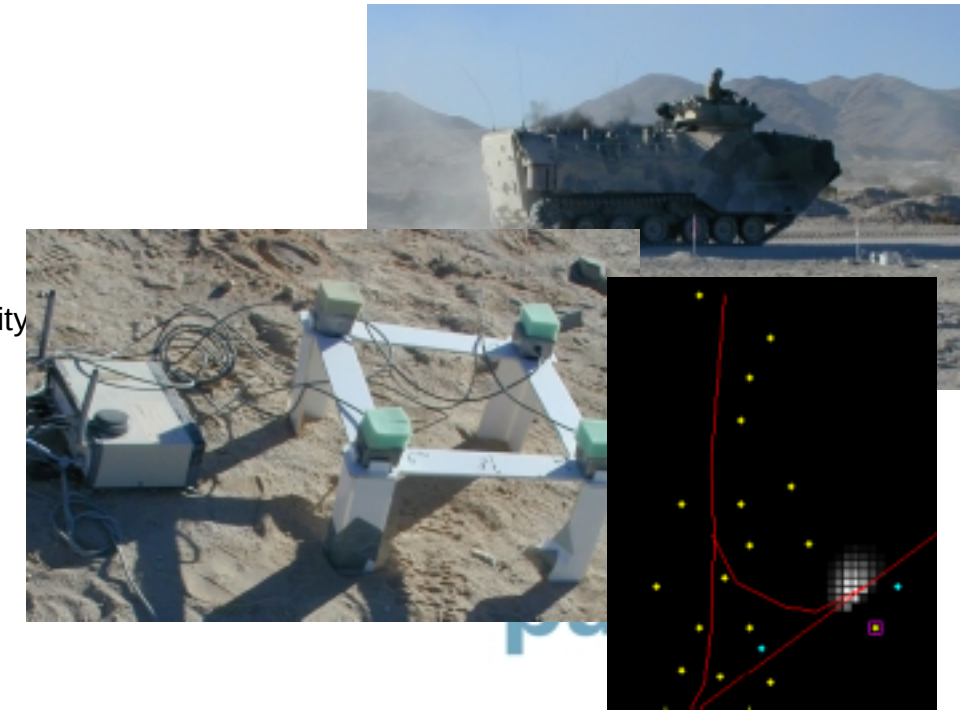
- IDSQ tracker
  - On site: 4-node test completed
  - In lab: 21-node test on SITEX02 data
- Beamformer (DOA)
  - 7 beamformers constructed
  - DOA algorithm tested (in collaboration with UCLA/Yao)
- Data collection
  - 3GB wideband data on tank, aav, humvee
  - 17MB detection data on aav and other targets of opportunity
- Service
  - Made and installed 32 microphone windscreens
  - Calibrated 32 microphone gains

Publications

- co-edited a special issue on CSIP
- 5 journal papers (3 accepted, 2 submitted)/6 invited talks/2 major press coverages

Methodologies

- Information-driven data diffusion
  - Maximize information gain while minimizing resource use
  - Energy-aware, lower latency
- IDSQ tracking
  - Non-CPA based, no road constraints, 2D tracking
  - Combine acoustic amplitude sensing with DOA estimates



PARC IDSQ Tracker in Action

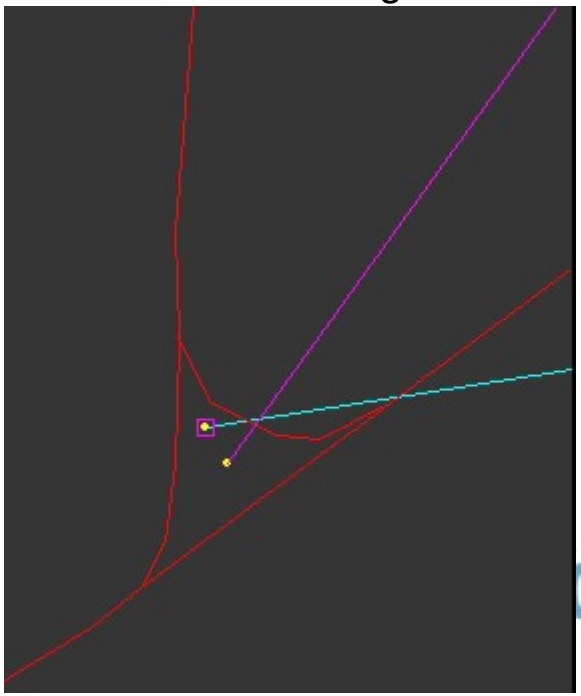
SensIT Experiment (video), 29 Palms, MCAGCC, November 2001

Tracking result (right) from post-processing acoustic amplitude data from 21 Sensoria wireless nodes (yellow dots).

Beamforming (Direction-of-arrival estimation)

Seven beamformers deployed at SITEX02, with an AAV in the background.

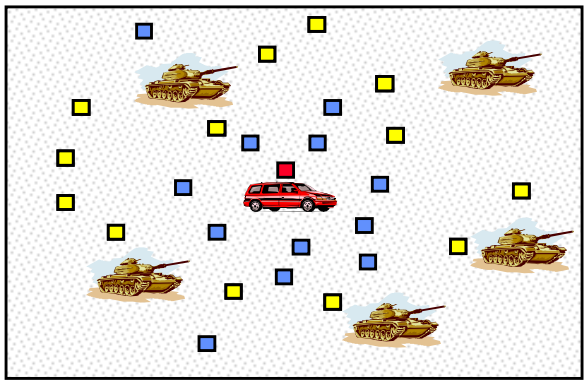
A 4-microphone beamformer



Two beams cross to locate a vehicle

Collaborative Sensemaking (CoSense): What are we trying to do?

Track multiple moving targets:
Which vehicle came from where?



Reason about global relations:
"Am I surrounded?"

Enable resource-aware, information-optimal sensor collaboration

- Problem: Tracking *non-local* spatio-temporal events or *low-observable* events
- Approach: Enable sensors to self-organize into *collaboration regions* based on information and resource constraints

A central problem: scalable mechanism to mediate between data and queries

Track groups: "Where is the group heading?" "How big is it?"

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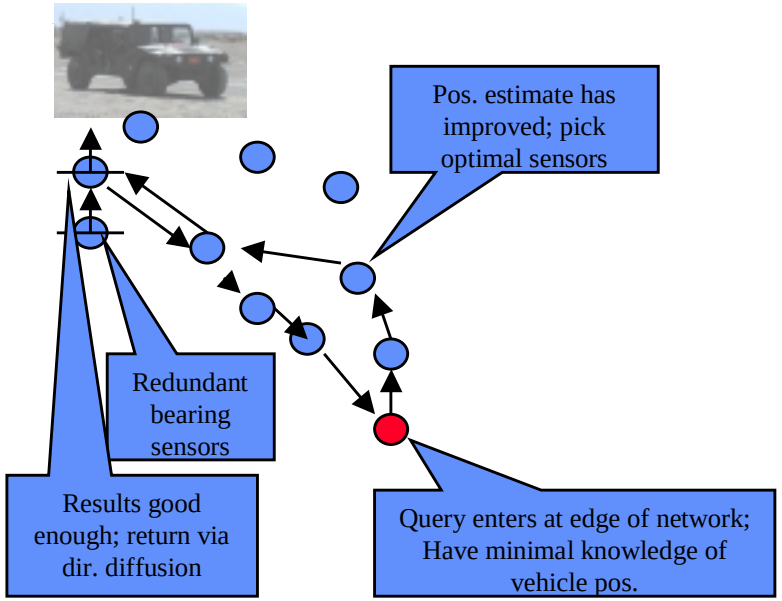
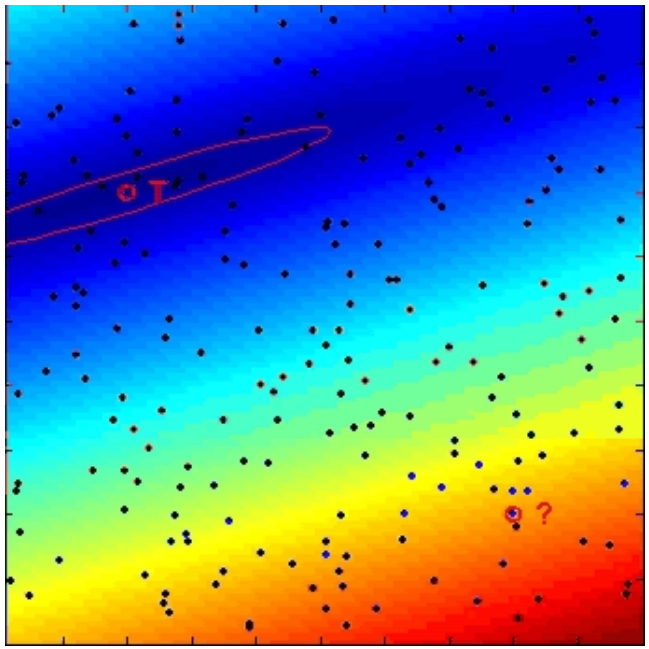
Actively Seek Out Information

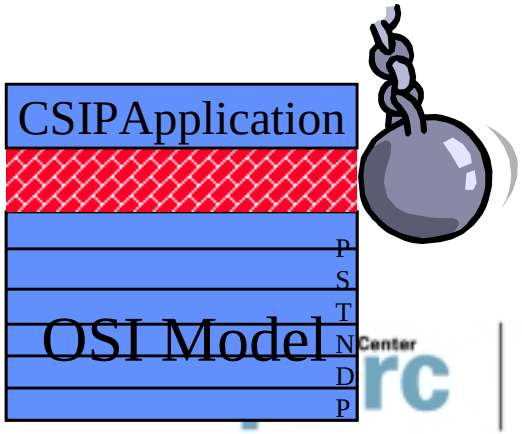
"Find the intruder" (minimize energy usage)





Break the barrier between *application* layer and *routing*

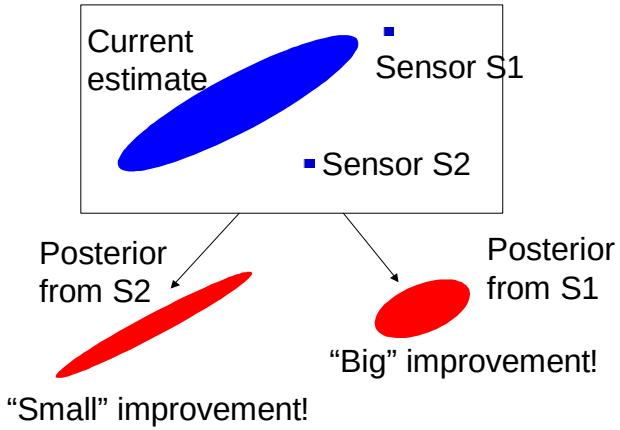
- Pick best info source considering network cost and information utility
- Implement selection in network, via routing decision.



IDSQ: Information Utility Measure

Select next sensor to collaborate so as to *maximize information* return while *minimizing latency & bandwidth* consumption

- Routing protocol to automatically direct a sensor query into regions of high information content (information utility measure)
- Tradeoff between maximum information gain and minimum transmission cost



Define dynamic constraints:

$$H(\vec{x}) = \alpha\,(\vec{x}-\vec{x}_T)^T\,\hat{\Sigma}^{-1}(\vec{x}-\vec{x}_T) + (1-\alpha)(\vec{x}-\vec{x}_S)^T(\vec{x}-\vec{x}_S)$$

Information utility: Mahalanobis Distance

Energy utility: Query path length

$\vec{x}$ Routing node position

$\vec{x}_T$ Target position

$\vec{x}_S$ Querying sensor position

α "Tradeoff" parameter

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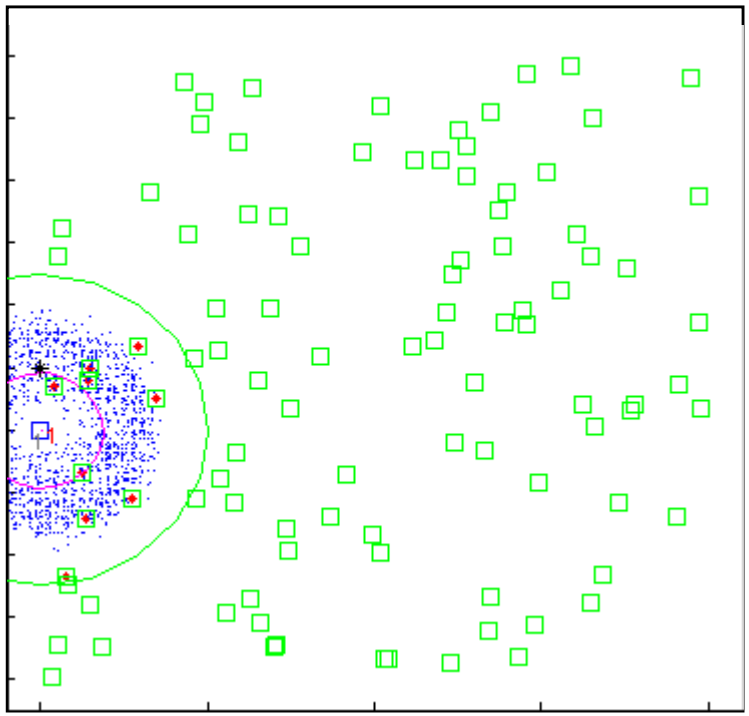
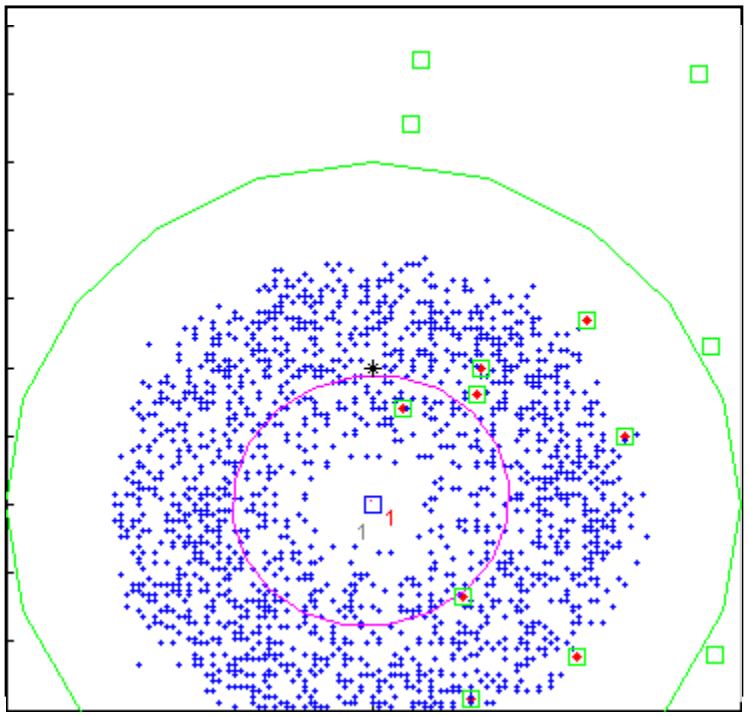
Tracking Moving Object

Only the leader node (blue square) carries belief state

- Choose sensor in the neighborhood with good information
- Hand off current belief to chosen sensor (new leader) and update belief



Target moving in straight line; Tracking using a sequential Monte Carlo algorithm



Close-up of target (particles show velocity vectors)

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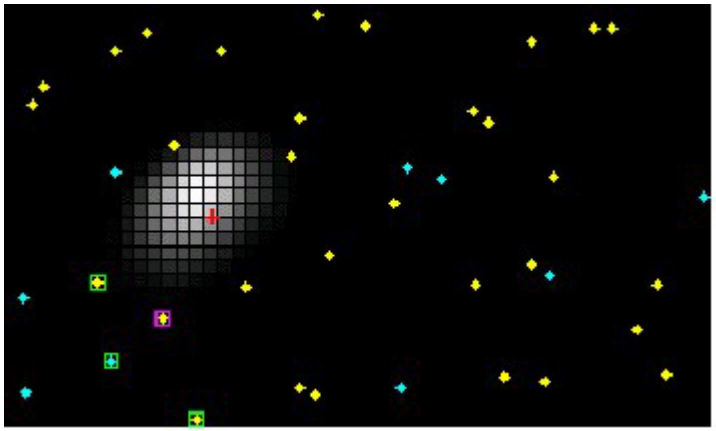
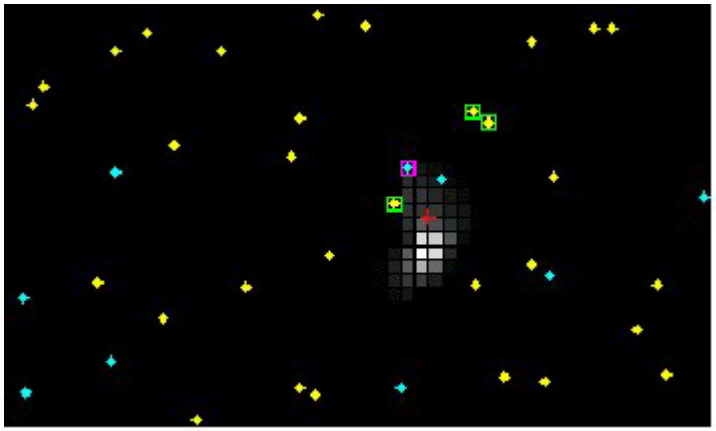
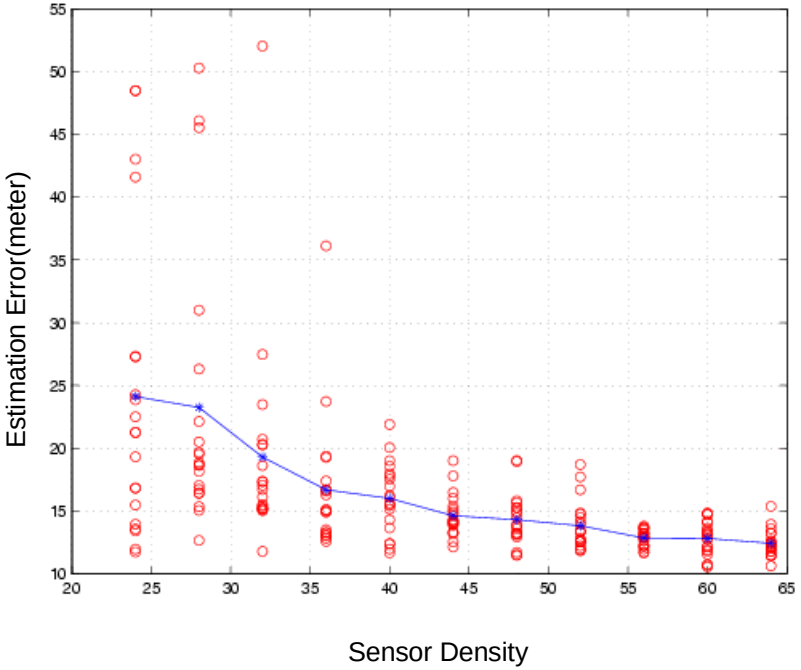
How track quality varies with sensor density

t=20



t=42





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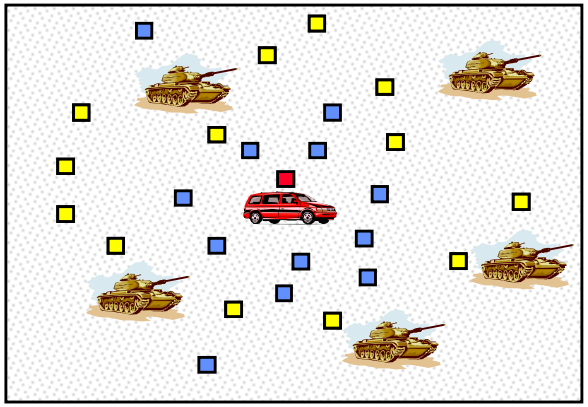
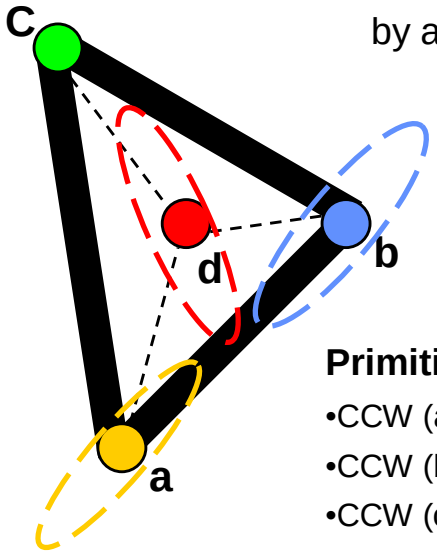
Tracking Geometric Relations

Answer queries regarding global relation between multiple objects

Approach: Establish global relation from primitive ones.
Select sensor to reduce global uncertainty.



Local reason about global structures: “Am I surrounded?”

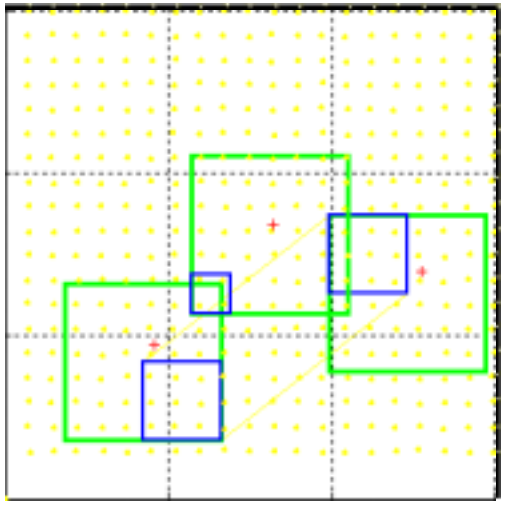


Global: is d surrounded by a, b, c?

Primitive:

- CCW (a, b, d)?
- CCW (b, c, d)?
- CCW (c, a, d)?

Relation decomposition and sensor test selection



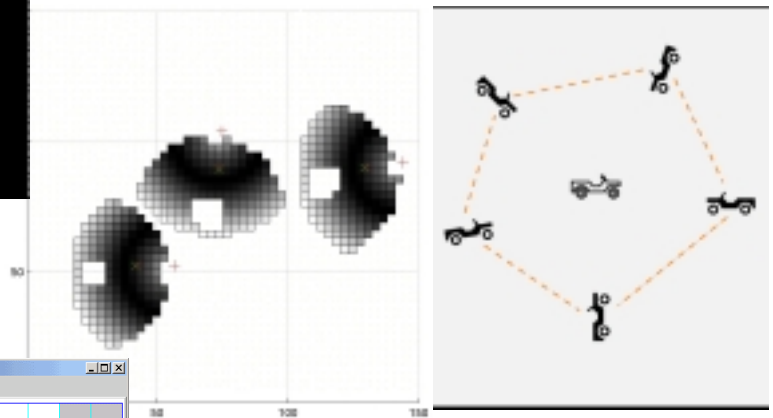
Hierarchical resolution of relations

CoSense Plan for 2002

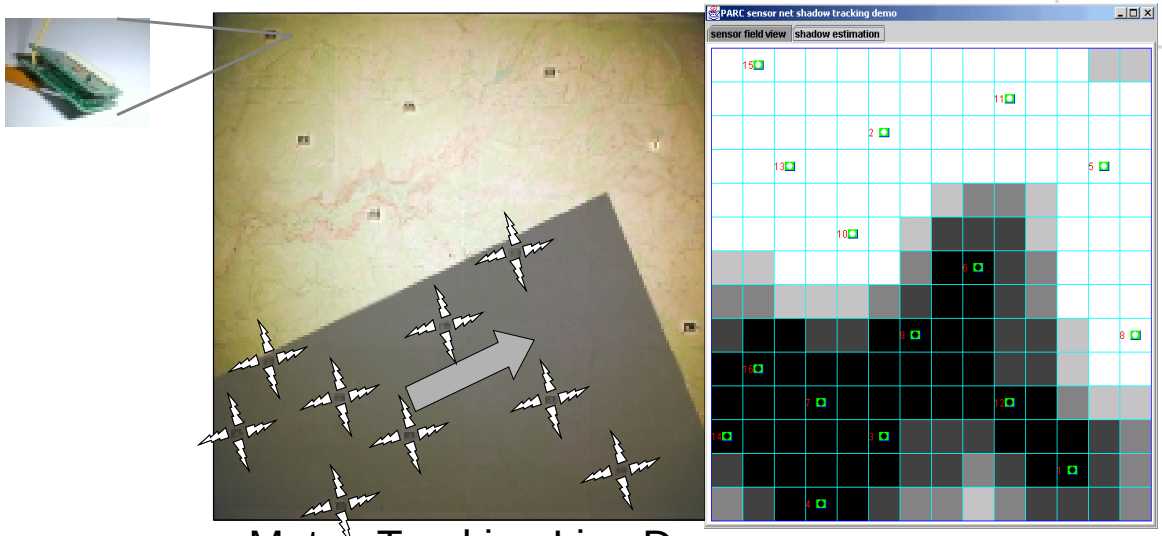
- Algorithm development
  - Characterize IDSQ tradeoff curves
    - Energy/accuracy/latency vs. sensor density
  - Multi-threaded IDSQ
  - Relational tracking
  - Multiple target tracking
    - Data association and MHM
- Collaboration with other teams
  - Continue to work with Yao/UCLA on beamforming
  - Continue to work with Mitter&Chu/MIT on MHM
  - Collaborate with Estrin/UCLA on geo-routing and in-network processing

Demos/posters

IDSQ Tracker Playback Demo



Relational Tracking Poster



Motes Tracking Live Demo

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DARPA CoSense Project:

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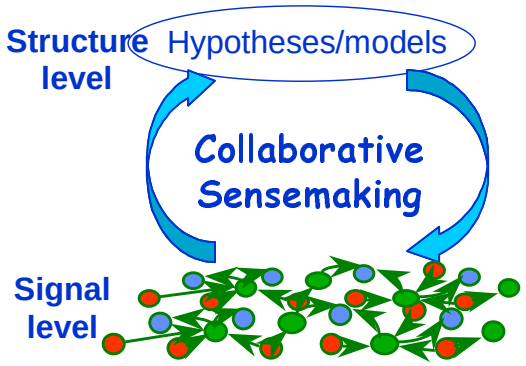


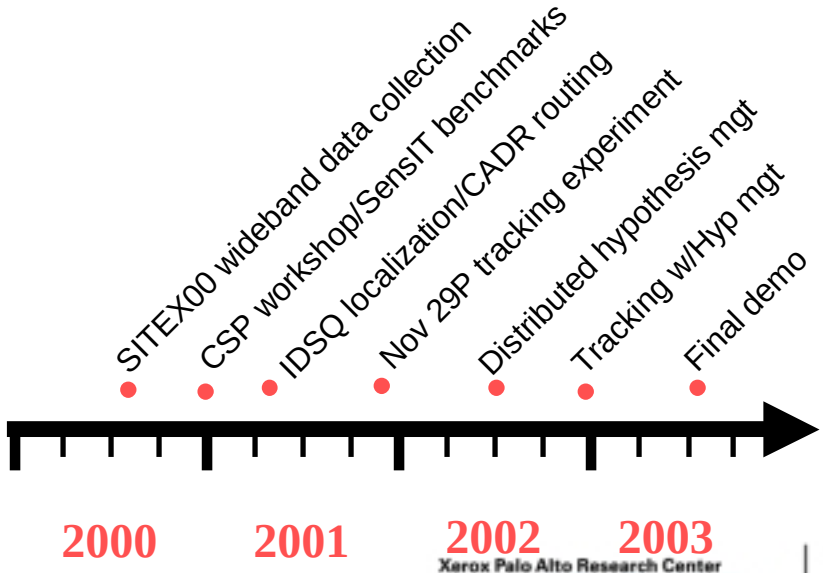
New Ideas

Blend signal- and structural-level analysis to enable reliable and timely tracking of non-local spatio-temporal or low-observable events in energy-constrained environment

- Multi-level collaborative signal analysis
- Information-directed sensing and communication

Impact

- Scalable to realistic target tracking problems
- Accurate, low-latency detection
- Energy-efficient



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